

Homo Optimus or Homo Ludditus

Source: <http://sci.tech-archive.net/Archive/sci.bio.evolution/2006-01/msg00625.html>

- *From:* "whitesickle@xxxxxxx" <whitesickle@xxxxxxx>
 - *Date:* Tue, 31 Jan 2006 16:24:03 -0500 (EST)
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The Future Evolution of Man
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1995

The rapid development in silicon and biotechnology could soon bring the human race to a critical point in its evolution where it can break free of its Darwinian biological roots. The potential impact is profound. The key thesis of this article is that the remaining lifetime of both Darwinian evolution and Homo Sapiens are both short and limited. Homo Sapiens' descendants will soon be able to seize control of their own evolution. To explain why this is so we will first examine how Darwinian evolution may be near its end for Homo Sapiens; then explore whether there are any fundamental biological limits which will block progress via genetic engineering; and finally examine how technology, and silicon in particular, can help us transcend these barriers.

Understanding Evolution

Homo Sapiens have now reached a position where three significant developments could radically change the evolutionary mechanisms. First, he has learned the fundamental concepts of evolution and thus can start using them, rather than being driven by them. Secondly, he has become able to manipulate his own genome directly, making Lamarckian evolution a possibility; although in this case the inheritance would be of desired, rather than acquired, characteristics. Finally, and most significantly, he has begun to create artificial life systems that may eventually supplant the whole notion of carbon-based life. Homo Sapiens is now able to take control of both the speciation process and the move from carbon to silicon life forms. We believe this change is inevitable.

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Most species are driven by the present evolutionary currents and the genome they have historically evolved. Homo sapiens is the first species to understand its own origins and, in doing so, is now able to see dimly its own future and consider manipulating it directly by adjusting its own genome. Genetic engineering opens the possibility for a species that evolves through Lamarckian evolution – directly manipulating its offspring's genome to include traits the parents consider valuable. This gives us the potential to drive the evolutionary process where we choose, not by a slow chance mutation driven by external pressure, but by a directive targeting.

However, there may be biological limits to Homo Sapiens future progression. Genetic engineering is viewed as a tool to gain robust, long-lived, disease-free, super-athletic bodies. We shall probably not see any profound change in our nature if this is the only use to which we put our evolutionary knowledge. There are much deeper driving forces to evolution than simply lifetime or health. The future evolution of Homo sapiens depends crucially on understanding the role energy and entropy processing plays.

Survival favours those organisms that efficiently gather and consume energy. Although the efficiency with which an organism exploits the energy sources is a strong selective force, there is a more powerful form of selection: the ability to identify the energy sources in the first place. This requires processing information about the environment the organism lives in. All living creatures function as information processors. They take in information about the environment around them, process it, and then use it to locate and secure the necessary means for survival. We are essentially entropy engines. The more efficiently organisms extract and process information from the environment, the more successfully they can continue their, and their offspring's, existence.

Homo Sapiens have succeeded in occupying so many ecological niches because, amongst land animals, it has the most powerful processor for the size of body. Systems or organisms that are more efficient at information processing could one day supplant Homo Sapiens from this general environment. Notice that they do not need to have 'human intelligence' to process and use information about the environment more efficiently than Homo Sapiens. A silicon chip, embodied in a suitable manner, may defeat a human through the sheer grunt of massed information processing without ever being labelled as intelligent. This happens already in limited domains such as chess playing.

Controlling evolution

The key question then is: can we improve our brains? Let us first consider the 'natural' route. All species have evolved currently using the random creativity of mutations and the selective pressures of the environment. The organisms that could be evolved in this manner may be

limited in scope by the types of self-ordered structures that could undergo such Darwinian evolution (see S. Kaufmann's "The Origins of Order"). However, this does not indicate whether there are any detailed limitations to, say, brain sizes. Rather more importantly, it has been argued that Homo Sapiens' control of the environment, and mobility around it, has already removed one key mechanism – local isolation – that was believed to drive speciation and thus evolution (see e.g. W. Calvin's 'The Ascent of Mind'). Homo sapiens may have limited his natural evolutionary ability by his very success at exploiting a wide range of ecological niches. This in part is dictated by our sensory organs, physiology, and physical attributes, as well as processing power. We are not wholly constrained by our wet ware (brain) power.

If natural evolution is limited can we tinker with our own genome to drive the process faster? To improve the processing of information, Homo Sapiens would need to improve the power of his central nervous system and, particularly, the brain. Is it possible, genetically or otherwise, to improve the brain or are there limits to neural processing power? Are there other media where completely new evolutionary driving forces can come into play apart from carbon? The last two billion years of information processing has been based solely on carbon-based molecular systems.

A common misunderstanding of the evolutionary process is to believe that it is possible to continue progress indefinitely. Unfortunately there are real, physical limitations on biological organs. Good examples include the limitations on the size to which insects can grow caused by oxygen diffusion limits, or the maximum size of a mammal before its legs can not take the strain of its weight. Since we are considering information processing here, the key issue is how large could we usefully make the brain. In this model the brain is viewed as a control system, whose job it is to make the best informed, most rapid, decision by processing as much information about the world and comparing it with as large a memory trace as possible. We define useful intelligence as a product of processing speed and the amount of memory which an organism employs to make decisions on the incoming environmental information. An organism which can make a decision faster, using more information and memory, can thus be considered more intelligent.

We have recently made some detailed calculations on this issue, which relate to wider issues of system intelligence. The results of these calculations show that, using cell-based neurones, the brain is limited to about 20 cm in diameter and to a maximum effective intelligence 20–50% greater than we currently possess. This is because of the time necessary to co-ordinate and process all the information that could be relevant to a particular issue. The value is the result of a whole set of trade-offs between synaptic density, signal transmission speed, processing speed, interconnectivity and thermal limits. Of course, it is possible to store more, and process less, information; but this does not make the generic intelligence or information processing improve.

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The more information processed and co-ordinated the better the overall system is at exploiting the environment. The same calculations can be used to show why neuron interconnectivity is of the order one thousand synapses per neuron, and how the transmission and processing delays are ideally matched.

The human brain is an information processor, the more information it can process in making a decision the better. If we assume the problem is to compare some new input with previous memories then the limit will be the number of memories we can compare per unit time. The minimum response time will be one clock cycle – in the case of the brain the pulse width (about 10ms). In this time the pulse must transverse all the synapses in the brain. The time to transit the brain is a function of the nerve cell diameter (larger = faster) and the brain diameter. As we make the nerves faster the packing goes down and thus the distance between synapses up. This offsets a lot of the speed gain. Synaptic processing takes time (1–2 ms). The more synapses the pulse crosses the slower it will be. In the brain there are 10^{14} synapses. Full interconnection increases the wiring and thus decreases the packing density, low interconnectivity increases the number of synapses traversed but decreases the distance travelled. Clearly there is a trade-off. The final limit is the need to plumb in cooling and energy supplies in the form of blood vessels. 7% of the brain is plumbing, is the size is double this increases to 14% and continues doubling with increasing size. This checks and balances between transmission time, processing time and plumbing mean that the brain can only process about 20% more information than our brains do currently – and only then by doubling the size. Of course our brains may be inefficiently wired but the ultimate wiring limit is near our current brain size.

Drugs or genetic engineering would need to improve both synaptic transmission times and neural transmission speeds to enhance the brain's processing performance. Neural transmission speed is a fundamental feature of biological membranes, since it evolved from the very mechanisms that preserve an action potential across all cell membranes. It may prove impossible to 'tinker' with it. Currently, biological nerve evolution has taken the course of wrapping the nerve with a gapped insulator and leaving the underlying chemical technology alone. Further improvements need a change of 'hardware', perhaps we would need to evolve electronic conduction along polymers to produce a significant increase in intelligence. Small enhancements via drugs or genetic engineering which produce, say, a factor of ten improvement just delay machine superiority by about 5 years.

The human genome project will be completed soon. At that point, a combination of man and computer search will be able to identify the genes needed to produce people of any chosen characteristics. Someone, somewhere will produce an elite race of people, smart, agile and disease resistant. We call this optimised human Homo optimus. While they may not represent a new species in the strict sense, they may well think of themselves as such, and they will be the first generation

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resulting from Lamarckian evolution. They will represent a key change of direction in evolution. Unfortunately, the timing of their arrival will make them largely irrelevant, as we will see.

Birth of a new life form: silicon systems

It is clear that the progress in silicon technology will continue for many years yet. If we simply extrapolate current trends, with progress continuing at current rates, we can expect the descendants of our desktop computers to be at least 50 000 times faster with at least 50 000 times more memory by 2015. A typical machine then processing at about 5 million MIPS with 1 TByte of RAM. However, such extrapolation ignores the extra assistance that we can expect from computers as they progress. Ten years ago, computers began to assist with laying out circuits, now they do this far faster than people. As they become faster and more intelligent, with access to a rapidly growing world knowledge base and a growing range of tools, they will assist and eventually replace us in more and more fields. The evolution of silicon will thus eventually be driven by silicon devices, rather than carbon based devices such as us. So the above figure of 50,000 may turn out to be a gross underestimate and a figure nearer 1,000,000 fold increase over the performance today may be nearer the mark. In comparison the limits referred to above give the human brain a processing power of around 1000 million million ops/s, with a memory of 10 TBytes. We suppose here that future computing devices will remain silicon based. This may not be true, and we acknowledge that other materials may prove better, and indeed there may be a move away from electronics to photonics, a merging of the two, as well as links to carbon based systems. The consequences however are largely material independent since these alternatives are unlikely to replace silicon unless they improve processing speeds, storage density, power consumption per MIP and speed up the rate of progress.

Computers are already helping us to become smarter. Without them we would have no understanding of Fractals, chaos and other complex phenomena. But gaining extra assistance from machines is not new – it has happened since we used the first tool. When all we had was slide rules or log tables, the invention of the first computers was a big step, which accelerated our calculations enormously. However, people were too short sighted to see that eventually computers would become so fast and so cheap that they would revolutionise not only calculations in well defined areas of arithmetic, but also assist with all kinds of information processing. Early electronics was almost entirely designed by man, but computers gradually took on board more and more of the design work, albeit mundane – checking logic here, routing a circuit there. They are still taking on more, automating ever more of the work and freeing people to do other work. In fact, we have now reached the point where our total reliance on technology is axiomatic. We no longer bake bread, smelt steel, weld cars or assemble TV sets – machines do! Turn off the communications systems and computers and a large proportion of human kind would die!!

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Technology feedback will make succeeding generations of computers arrive faster, each successive generation helping even more in the development of the next. This is a feedback loop with a degree of feedforward – and it is positive. With the benefit of hindsight, we can see that it has applied throughout history. Many inventions or discoveries have not only been useful in their own right, but have accelerated progress within their fields (and often others too). The more physics and mathematics we learned, the more rapidly these fields developed. The more tools we make, the more tools we can make with them. The faster we could travel, the faster materials for making transport could be gathered. This continuing positive technology feedback in the computer development cycle will push computer development faster and faster, with humans eventually cut out of the development cycle completely. When a particular bottleneck prevents further development along a particular route (such as smaller device size), they will find other avenues to bypass the restriction, just as we always have so far.

This technology feedback will bring us super-smart computers in a very short time from now. Before they become as good as people at computer design, we can only expect slow acceleration in their evolution. However, being optimistic about human capabilities, we expect computers to surpass us in most fields by 2015. As we approach the point of human-computer equivalence, progress will accelerate faster. As we pass it, the progress curve takes a very rapid turn upwards which will not stop until the development cycle is suddenly stopped by ultimate barriers imposed by physics – or God. As yet, we are not aware of any such limits, so we expect computers at least millions of times smarter than us by 2030 – what they will ultimately achieve is guesswork.

We can expect these computers to change whole fields of communications, business and society. They will not however emulate human intelligence: rather they will develop in parallel surpassing humans in many tasks for which they are best suitable, opening new fields not currently accessible. We can expect computers to evolve their own code and rapidly move to a level of complexity beyond our understanding. Whether they are more intelligent than us will become as relevant as asking whether your car is as fast as your PC. Computers generally require ever more capacity for machine-machine communications. Binary is already the dominant language on planet earth with today's machines having more conversations in 24 hours the whole of human kind since the birth of Eve. As they grow more powerful, automatic machine-machine communications will swamp human-human communication completely. The information superhighway is really about machines talking – distributed intelligence – a distributed being: current arguments about whether it is possible to justify broadband communications will become a strange historical tale.

A mistake which we often make in any field is to assume progress will continue at today's rates. Consequently, we tend to put small

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advances in the near future and large advances in the very distant future – even centuries away. But technology feedback in computing will not just bring us smarter computers, it will accelerate development in every other field. Advances that might otherwise take many decades may only require a few months or years when we get ever smarter computers. We should even ask ourselves whether it is worth tackling some big problems yet, since our lengthy efforts now may only save a very short time later.

As growing computer intelligence accelerates progress in communications, materials, biotechnology, energy, robotics and cybernetics, earth and space exploration, developments in these areas will feed back positively into further computer development, which impacts back into these fields. Positive feedback thus permeates the whole of technology. So we are about to enter an era of explosive technological development. Current research will yield earlier results. Technologies which were thought to be far in the future will be brought much closer. Scientific understanding will develop rapidly – though much of it may reside only within the computers and may be beyond our simple minds. How might this affect evolution?

In the same time frame as we learn how to manipulate our own genome to produce Homo optimus, developments in computer technology will finally bring about smart machines. There are many possible routes to this realisation and we cannot be certain which will win, but we can be sure one of them will. This artificial intelligence will probably borrow from the increased understanding of how the human brain works, but will also take from other fields of knowledge too, and may even have a strong evolutionary or self learning element. In any case, we can expect the nature of this intelligence to have some similarities with our own, but not to be the same. Although intelligence in a machine does not equate to life as we know it, we may find that the differences are cosmetic, and we may begin to recognise intelligent machines as a new life form, another evolutionary offshoot of Homo Sapiens. We cannot insist that these machines must be conscious and self aware to be classified as life – we do not make that rule for organic life – but it is probable that many will become self aware in this time frame.

As with all computers, and indeed biological organisms, there will be a spread in levels of intelligence. Some machines will remain completely dumb, others may be much more sophisticated than ourselves. There will be many varieties of these machines, many species. The first generation or two will have been designed to assist mankind. Their intelligence will be very useful, complementing our own, so that together we will progress much faster. However, we cannot assume that their offspring will always be our friends. If they are designed to optimise their success in their environment, and have independent thought, which they will, then they may well evolve far beyond us, and if we stay still, we could eventually be like their pets, instead of the other way round. Obviously, many such nightmare scenarios have been explored in science fiction. But we need not remain in stasis. As we will show later, our own evolution can continue.

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Predicting the future of evolution with certainty is clearly impossible – but we should be contemplating the possibilities. Here is our projection – best guess – as to our ultimate fate.

The future evolution of intelligent life forms
Robotus primus

For a time at least, we will be the second smartest beings on Earth. Computers will probably surpass us in intelligence around 2015, and it will be some time after that before they develop the technology to bring us up to speed. So the first major impact is a new intelligence sharing the planet. We call this Robotus primus. In the 2015 time frame, it is reasonable to expect that these computers could be accompanied by sufficiently developed robotics technology to make them fully mobile, though their 'minds' are not tied to any particular machine or location – but distributed. The early generations will rely on relatively crude robots, but these will quickly evolve into sophisticated androids. We stress again that Robotus primus is not the android itself, which is merely a tool, but the intelligent mind inside. We will of course see many grades of computer intelligence, just as we do now. A toaster cleverer than man would seem somewhat superfluous. Rapid speciation of this artificial intelligence can be expected, with elite models rapidly losing position to their descendants.

Homo cyberneticus

Even in 1995, people have developed silicon chips which can interface directly to human nerve cells. Various cybernetic prostheses and other extensions to the body are in development. Others have demonstrated that thoughts can be detected and recognised, even without physical contact with the body. It seems reasonable to assume that it will not be long before a computer can interface directly to a human, producing artificial senses and reading the person's thoughts. Although no-one has yet demonstrated a means of putting thoughts into a human, it does not seem unreasonable to assume it can be done, perhaps by creating appropriate electric fields at appropriate points, which again should not require any direct contact.

We thus expect that at some point after human machine equivalence, perhaps just a few years, the technology will be developed to make a full duplex mind link between man and machine. Then we will be able to enhance our mental ability by using external processing as an adjunct to our own brains. Since by this time the machines will be much smarter than we are, this will be a large step for mankind.

Those people who accept this technology will instantly have a great advantage over those who do not (and there will be many). In the same way that people rejecting IT today are a dying species, excluded from a new workplace and society by their own hand, then future rejections

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will be more exaggerated and speedy. So they will be so far removed from Homo Sapiens that they will in effect be the start of a new species, which we call Homo cyberneticus. As the technology rapidly develops, the differences between Homo cyberneticus and Homo Sapiens will increase. However, since the early Homo cyberneticus is a conjunction of conventional humans with machines, there is obviously room for improvement.

Homo hybridus

It is likely that many of the people who accept cybernetic enhancement would lend themselves to genetic enhancement too, or would allow enhancement of their offspring. A further branch of optimised biological man with some cybernetic links can therefore be expected. Perhaps their genes could be selected to work better with cybernetics than conventional organisms. We call this species Homo hybridus. This species is the one which makes Homo optimus rather redundant, very soon after its creation. Similarly, the first generation of Homo cyberneticus would become obsolete, since the human bodies connected would be inferior to those of Homo hybridus.

Changes generally bring stress, and this often leads to conflict. The many new species would not coexist easily with Homo ludditus, and there would be some competition for resources between these species too. Whether peaceful coexistence is possible or not, it would seem unlikely, give the well known nature of Homo ludditus. Science fiction has already begun exploring this conflict, with The Forbin Project, Terminator 1 & 2 being famous examples. However, in Terminator, Homo ludditus wins, which seems an unlikely outcome. Perhaps the 2200 estimate for human extinction seems optimistic in this light.

We can also expect friction within our species as machine intelligence improves. The industrial revolution reduced the value of muscle power and in the same way computer evolution will reduce the value of brain power – to zero. One by one, jobs will be lost to machines, whether robots or computers. Our corporations will be run and staffed entirely by machines. Those using humans will not be able to compete and will go under. People will have fewer and fewer attributes to sell. Of course, production and output could greatly increase while human input could decrease, so we could all have a better quality of life without having to work. A fully automated economy could still be bigger than one which involves people. 20th century economics will not work in the future – the cracks are already getting bigger – machines take out delay and uncertainty, displace humans and reveal economics for what it is, a game of numbers in a spread sheet! . Our current concepts of wealth, money and ownership will take a severe battering. Perhaps we will enter an age of leisure, where any work we do is voluntary and is based on spending time with other people. Or perhaps people will be overtaken by fear as they lose control over what is happening. Then wars might break out. In any case, this age will not last long as we are absorbed into the higher existence offered by the machine world.

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When a direct link from the computer into the human brain is achieved, thought transmission will give us telepathic communication not only with machines but with other people. We will be able to enjoy a shared consciousness with other humans and synthetic intelligences such as *Robotus primus*. Our evolution to *Homo machinus* will therefore be set against the background of a global consciousness. Individuals will still exist, but we will also have a group existence. As we achieve this link, we will also be able to make copies of our minds in the machine world – a backup in case of accident. We will become immortal, even if our mobility and physical existence is restricted until a suitable replacement body or android is produced for us. Death will be just a memory of a primitive past.

We may have an alter ego in the machine, or many. We may try out different situations or life decisions, or different personalities. These alter egos could occasionally make trips into the 'real world', time sharing robotic bodies. These bodies would not necessarily be humanoid, so we could really be the 'fly on the wall'. Procreation could be a highly creative act, with any number of people combining (N – Sex) selected characteristics from themselves or their imaginations to create new beings. Each person could give rise to large numbers of personal offspring in this way. The number of beings which could coexist may be limited by the size of the host infrastructure, but they could timeshare or lie dormant until more space is created.

Homo machinus

The two enhancements of biological optimisation and connection to synthetic intelligence are not equal in potential impact. Due to speed of development, we can reasonably assume that some of each of the above species would exist, but we can argue that they would soon become obsolete. *Homo optimus*, would have been left behind by *Homo cyberneticus* and they in turn would be succeeded by *Homo hybridus*. However, as the mind machine link becomes completely transparent, and as materials and cybernetic technology improve, *Homo hybridus* would rapidly find most of its intelligence and most of its physical capability residing in the machine rather than the organic side. As the human mind gradually moves further into the machine world, it would become apparent that the organic body is redundant. If it died, it would be a minor inconvenience, requiring a cybernetic replacement to be commissioned. As the bodies die out, *Homo hybridus* would too, becoming a non corporeal being, which we call *Homo machinus*.

This new species retains some elements of the earlier human race, but is vastly more intelligent and has access to whatever physical capability is required. It can travel at the speed of light, exist in many places at once, and would be essentially immortal. It would coexist with *Robotus primus*, but we could expect that the two would closely interact and may quickly converge.

Summarising, we can draw an outline of or projection of human evolution from the distant past to the relatively near future.

Space exploration is currently very expensive, so we haven't got far yet. However, when we exist only as information within a machine, we could be copied into a very small device, encapsulated in a very small shell with some nano-technology machines, nanites. By this time, we could expect that nanites would be able to make replicas of themselves, and of anything else we desire. These small shells would be like seeds. We could accelerate them to near light speeds and send them off to other planets around other stars. The nanites would be able to fabricate a suitable environment and suitable body for us, and then upload us into them. The environmental requirements of Homo machinus might not be very demanding. We may not even be limited by the speed of light, if we can master warp drive, wormholes or tachyon transmission, all of which we know are possible in principle. Surely a few years of research by mid 21st century super-beings will crack the problems of bringing these principles to fruition. Many other exciting areas previously beyond us will be a natural part of our everyday existence.

Conclusions

It is certain that there will be strong reaction to this tinkering with the human species. Not everyone will welcome it, either for religious or ethical reasons, or simple preference. Many people will dissociate themselves from genetic manipulation or cybernetic technology. These people will remain as conventional Homo Sapiens (we will rename them Homo ludditus for obvious reasons). They would at best have to co-exist with these other human offshoots, who would dwarf them mentally and physically. They would not be able to compete, and they may have the same relationship to the human variants as pets do today. Knowing that they too could at any time accept the new technology and move onto the higher planes of existence would probably rapidly diminish the numbers of Homo ludditus. The race might just fizzle out due to lack of interest after a couple of centuries of stubborn resistance, say by 2200. Homo Sapiens would be the first species on Earth to have become voluntarily extinct.

There are limits to Homo Sapiens, limits to the environmental stress planet earth can withstand, and as a species we may be close to extinction, to be replaced by a whole range of silicon life forms. As computers become more powerful they will take over, first driving their own technological developments through automated design and self-evolving programs, and then in other fields. Once free of carbon, or aided directly by silicon, the whole pace and nature of evolution will change.

Currently there are arguments that machines (in their current form) can never equal man's intelligence. These arguments are about as relevant as those of previous centuries relating to the number of angels that

can sit on a pin head, or indeed more recently, the existence and nature of hell. If machines beat us at processing information, and all the indications are they will increasingly do so, they may never need to directly equal our intelligence, they just need to circumvent it. They may also work out how to be 'similar' to our brains for themselves through the sheer processing power they possess. Early estimations of when this might happen made widely inaccurate assessments of human brain power. This should not obscure the inevitability of the process. one hundred years is very short in evolutionary terms. A combination of technology feedback and human limitations will soon change the fundamentals of society and biology. Homo Sapiens does not cope well with predicting or understanding exponential changes, many will fail to see the future coming until it is past.

Today we enjoy a rich environment of male and female, ethnic variety, cultural and education backgrounds. A society of minds! Soon this richness, limited by a given cerebral volume and left–right lobe connect, will be augmented by a third lobe – the machine. Thinking in a new way, and possessing new abilities we will see our abilities and imagination lifted. The question is; can we overcome our mental stasis through a symbiosis with machines, or will we go down fighting and be wiped out?

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